Desktop Teleradiology in Support of Rural Orthopedic Trauma Care

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Research has shown that diagnostic quality images for most teleradiology applications requires a sophisticated telemedicine system and access to a large amount of bandwidth. While the ideal standards have been set by those involved in evaluating teleradiology, these standards are impractical for many small rural heath centers which deliver routine trauma care. While there is no disagreement about the ultimate need for this level of teleradiology support, the purpose of this research was to determine whether Orthopedists would be able to read plain radiographs of orthopedic trauma injuries using a desktop teleradiology system in support of rural trauma care. ***Method****: Two radiology residents and two orthopedic residents viewed forty radiographs, twenty through a desktop teleradiology system and twenty in person. Diagnostic findings and certainty of diagnosis were recorded.* ***Findings****: There was no statistically significant difference between modalities in orthopedic residents' ability to correctly diagnose orthopedic trauma injuries. Further, for those instances when the diagnosis was imprecise, the residents were aware of their inability to make an accurate diagnosis.* ***Conclusion****: Although the study was relatively limited and further research needs to be done, the use of desktop teleradiology in support of rural orthopedic trauma consultation is a promising alternative to the more expensive forms of telemedicine technology.*

INTRODUCTION

In September, 1993, the Office of Rural Health Policy of the U.S. Department of Health and Human Services published a report entitled Rural TeleHealth: Telemedicine, Distance Education and Informatics for Rural Care.[1] In this report, there was a call for the creation of Rural Area Networks to support a variety of applications ranging from business to education and to mitigate the health care shortages often experienced in rural communities.

The report enumerated many obstacles to the creation of such networks, including costs, regulatory and legal issues, training and quality assurance mandates. However, the need for such networks was obvious and telemedicine had reached a point where it could have a significant impact on health care delivery, regardless of time or distance to providers.

One of the areas in which immediate access to quality health care is most critical is in the rural trauma center. There are relatively few Level I Trauma Centers in the United States and proportionately fewer in rural areas. Until 1996, there was only one Level I Trauma Center serving all of Northern New England and most of upper New York State. However, physical access to Fletcher Allen Health Care, the tertiary care center of the University of Vermont College of Medicine, was extremely difficult during winter months and even during the Summer required significant driving time from the outer limits of its catchment area.

VTMEDNET Plus

In 1995, Fletcher Allen began a pilot telemedicine project between two rural hospitals and the academic medical center.[2] Simultaneously, plans were developed for the creation of VTMEDNET Plus, the voice, image, and video enhancement to VTMEDNET, Vermont's health information network.[3] While the latter was predicated on data transmission, VTMEDNET Plus was grounded in telemedicine applications while supporting forms-based and intelligent e-mail, a World-Wide Web component, videoconferencing, and access to patient care and knowledge-based information.

While the initial pilot telemedicine network was built on leased T-1 lines using V-Tel equipment, there was a realization that leased line support would not be cot-effective, particularly in a growing managed care environment. This prompted a move to the use of ISDN using 384 kbps bandwidth for virtually all telemedicine access and a switch to Zydacron equipment for a multi-site expansion of the initial test-bed telemedicine network.

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Because the emphasis was on live, interactive consultation, image intensive applications such as telepathology (after an initial pilot study) and teleradiology were not promoted. However, there was a growing realization that the telemedicine network, to reach one of its original stated goals of supporting rural trauma care, would need to support basic teleradiology.

Teleradiology

Several researchers have compared current digital imaging technology with standard radiographs. Scott, et al, reported on the poor performance of seven senior radiology residents at interpreting "difficult" orthopedic fracture cases. The residents had an accuracy of 80.6% when evaluating 60 radiographs compared to a 59.6% accuracy when viewing 60 different cases present as digitized images on 1,280 x 1,024 pixel monitors.[4] Yamamoto, et al, had similar results when attempting to validate radiologists interpretation of fourteen cervical spine radiographs. The variability was attributed to the quality of the original films as a determining factor in teleradiology accuracy.[5]

In comparing digital images in both uncompressed and compressed JPEG (Joint Photographic Expert Group) format, Yamamoto, et al, found no difference in the resolution but a clinical trial comparing the two failed to validate this finding.[6] Mezrich, et al, tested the World-Wide Web as a distribution medium for text, images, sound, and cine for radiology consultations, however the researchers were unable to validate the medium as satisfactory for the application.[7]

Although some research has been disparaging in the use of teleradiology, specific, targeted uses, even with relatively low-cost technology, have been gaining wide-spread acceptance. Tyndall, et al, used video-based teleradiology to evaluate intraosseous lesions. With the control being use of a standard viewbox, and the experimental observers using an analog based system, there was no statistical difference in diagnostic outcomes between the two methods.[8] Coons, in an article reviewing teleradiology studies, suggested that cost savings, organizational efficiencies, and improved health care outcomes in rural and off-hours access to specialists support deployment of teleradiology systems, particularly when connected to emergency rooms.[9]

Kagetsu and Ablow studied 919 films generated in an emergency room between the hours of midnight and 8 am. The films were digitized to a 512 –512 x 8 bit matrix, compressed at a ratio of 2.5:1, and transmitted via 9600 baud modem. Both the teleradiology images and the original films were read, resulting in a 1.6% clinically significant error rate.[10] DeCorato, in a similar smaller study, found a 5% clinically significant discrepancy between the original radiographs and the teleradiology images.[11] However, both studies concluded that teleradiology could be both reliable and effective when used to support specific applications such as off-hours emergency room care.

Scott, et al, however, reached a different conclusion in a clinical trial in which researchers compared digitized and plain radiographs. Radiology staff and residents and emergency room staff and residents were used to evaluate 120 cases comprised of 62 musculoskeletal, 20 abdominal, and 38 chest films. One half of the cases were normal and served as controls. The results indicated that the digitized films were inferior in terms of the evaluator's diagnostic accuracy, although the authors did note that the study was designed to magnify differences by choosing particularly difficult cases.[12]

For the purposes of this study, another controversial area was explored. Debate exists between orthopedic surgeons and radiologists concerning the most appropriate specialty to read orthopedic radiographs. Clark, et al, retrospectively reviewed reports of 371 radiographic studies made by three board certified radiologists. The conclusions of this study were that there was enough error or missing descriptive information such that a clinical decision could not be made in a significant number of cases and that orthopedists' interpretation of radiographs should be accepted in most cases without a second opinion by a radiologist.[13]

Berbaum, et al, looked at the impact of the clinical history on the ability of orthopedists and radiologists to interpret radiographs and found that orthopedists are more adept at using clinical history in making a diagnosis and treatment plan than radiologists who tend to rely more on the evidence presented by the radiograph itself.[14] Bosse, et al, went one step farther by suggesting that the double reading of radiographs in trauma patients, first by the orthopedist and later by the

radiologist was almost always a waste of money in an era of cost containment. The researchers found that the orthopedist's reading was virtually 100% accurate compared to a 94-96% accuracy rate for radiologists. Further, all of the orthopedist readings were done at the time of diagnosis and initial management of the trauma event while the average time to reading of the radiographs for the radiologists was 5-7 days.[15]

In summary, while there is still a good deal of concern about the quality of the teleradiology image for interpretation of difficult cases, most researchers agree that the orthopedist is capable of reading orthopedic films and initiating management, whether those radiographs are on the original film of transmitted through a teleradiology mechanism.

METHODS

Most research done on the validation of teleradiology images has focused on the reading of digitized images. For the purposes of this study, real time analog images, converted to digital format for transmission to the remote site and then converted back to analog images for viewing. were used. Because the purpose of this study was to determine whether orthopedists using teleradiology at a Level I Trauma Center could support rural orthopedic trauma patients, the study design attempted to simulate, in terms of technology and severity of problems, what would be expected if the current, desktop-based video conferencing systems were to be deployed.

The telemedicine system consisted of 166 MHz PC desktop units equipped with 32 MB of RAM. Video was transmitted triple ISDN Basic Rate Interface (BRI) lines which provided a data transmission rate of 384 Kbps. HealthLink Networks systems utilized Zydacron Z250 videoconferencing boards and Zydacron Z208 BRI inverse multiplexer cards in each unit. An external pan-tilt-zoom camera was the primary camera source for the image capture. For the purpose of viewing the images, a 27" Sony Trinitron Color monitor was used.

A set of eighty cases of varying degrees of complexity, from all areas of orthopedics, were selected by the principal investigator. Several normal cases were also included to serve as controls. The presenting history and physical exam findings, as would be available in a real-time teleradiology emergency orthopedic trauma consultation, were distilled into a concise, standardized format and made available to the reviewers. The cases were divided into two groups of twenty based on their randomly assigned medical record number. Reviewers consisted of two Chief Orthopedic Residents and two Senior Radiology Residents. Attendings were not used because of their specialization and it was felt that chief and senior residents preparing for their respective boards would have a more comprehensive generalized knowledge.

Two pairs, each consisting of a Radiology Resident and an Orthopedic Resident, were used for each case. One set read the radiograph at an x-ray view box while the other set read the x-ray via teleradiology at a remote site. After the first twenty cases, the review groups switched places, with those initially reading from the light box now reading the images through the teleradiology system and vice versa.

This structure enabled one of the Orthopedists to act as the other's control and each of the radiologists to serve as the benchmark for each case. There was no attempt to use a single evaluator for each reading modality for a single case because of the substantial learning effect encountered with only forty cases. The gold standard to which the reviewer's diagnosis was compared was the diagnosis of the attending Orthopedic Surgeon who treated the case, as noted on the patient record.

Outcome measures for each examiner and each case consisted of the diagnosis and relative certainty of the diagnosis. An exact diagnosis, one which replicated that of the attending Orthopedic Surgeon and on which a clinical decision could be made, was awarded two points. An imprecise diagnosis, one on which a clinical decision could not be made, was awarded one point. No points were awarded for a wrong diagnosis. Certainty of diagnosis, as indicated by the reviewer, was made on a scale of 1 to 5, with 5 indicating complete certainty and 1 indicating complete uncertainty.

Accuracy of diagnosis was dichotomized to either precise or wrong, with the assumption that imprecise diagnoses which did not allow clinical decision making were inherently wrong. 2 x 2 tables were constructed comparing those x-rays read in person with those x-rays read through teleradiology, and comparing those read by Orthopedists with those read by Radiologists.

McNemar's Test was used to determine significance. Kendall's Tau non-parametric correlation was used to correlate the exactness of diagnosis with the certainty of diagnosis.

RESULTS

A total of eighty cases were reviewed, forty by Radiologists and forty by Orthopedists. The telemedicine and "in person" diagnosis was concordant in 64 of 80 (80%) cases. More specifically, a precise consensus diagnosis was made in 53 of 80 (66%) cases. When stratified by physician type, the proportion of precise consensus diagnoses was 31 in 40 (78%) for Orthopedists and 22 in 40 (55%) for Radiologists.

The proportion of incorrect diagnoses made via telemedicine when a precise diagnosis was made "in person" was 6 of 40 (15%) cases for Orthopedists and 6 of 40 (15%) cases for Radiologists.

For the Orthopedists, the percentage of precise diagnoses was 93% for reading "in person" vs. 80% for reading via telemedicine, which are not significantly different by McNemar's Test ($p=0.13$). For the Radiologists, the percentage of precise diagnoses was 70% for reading "in person" vs. 63% for reading via telemedicine, which are also not significantly different ($p=0.51$).

Percent of Precise Diagnosis By Viewing Modality

	Telemedicine	Radiographs
Orthopedists	80%	93%
Radiologists	63%	70%

In looking at the differences in results between Orthopedists and Radiologists, using McNemar's test, there was a statistically significant difference between our Orthopedists and Radiologists in reading films in person ($p=0.012$) but not when reading films via telemedicine ($p=0.920$).

A comparison of accuracy of diagnosis was made with certainty of diagnosis. Using Kendall's Tau, non-parametric correlation measure, a significant relationship between diagnostic accuracy and certainty of the diagnosis was identified only for Orthopedists reading X-rays via telemedicine ($p=0.001$). The Orthopedists and Radiologists in the study had essentially the same confidence in their diagnosis when reading X-rays in person ($p=1.000$), but differed significantly when reading films via telemedicine ($p=0.039$). Additionally, there was a significant difference in certainty and accuracy between the two viewing modalities for both the Orthopedists and the Radiologists (McNemar's Test: Orthopedists, $p=0.016$ and Radiologists, $p<0.001$).

DISCUSSION / CONCLUSION

In this study, there was no statistical difference in Orthopedists' or Radiologists' ability to generate a correct diagnosis between X-rays viewed in person and those viewed via Telemedicine. There is, however, a statistically significant difference between the Orthopedists' and Radiologists' ability to make a correct diagnosis when reading X-rays in person but not when reading X-rays via telemedicine. There is also a statistically significant correlation between the Orthopedists' accuracy of diagnosis and the certainty of that diagnosis when reading X-rays via Telemedicine, but not when reading X-rays in person. There was not a significant relationship in either viewing modality for the Radiologists. Lastly, there was no identifiable relationship between diagnostic accuracy or certainty when the cases were subgrouped by Orthopedic sub-specialty.

This was a pilot study to evaluate the efficacy of the extant telemedicine system in covering orthopedic consultations from distant sites. An attempt was made to simulate the expected conditions from an outlying hospital's emergency department to the Level I Trauma Center. Caution must be exercised when making conclusions from a cohort of 40 cases. None-the-less, the results are encouraging. It is understood that the imaging system is not particularly well suited for the transmission of static images, and certainly does not do so at the resolution of that evaluated or even close to that of currently available teleradiology systems in previously published studies of teleradiology. However, as stated, the aim was to evaluate the present system within the limitations defined by the circumstances of use. This has not been previously reported in the literature.

The goal was not to explore the differences between Radiologists' and Orthopedists' ability to make diagnoses, rather the Radiologists were

included as a benchmark measure for comparison to previously recorded results in the area of teleradiology. It is assumed, however, that the addition of specifically relevant clinical information, as ascribed to standard orthopedic practice, coupled with knowledge of treatments for specific injuries, allows a higher level of accuracy of diagnosis which is essential for clinical decision making.

The correlation between certainty and accuracy for the Orthopedists when reading films via Telemedicine is extremely important and validates this study for its intended purpose. This theoretically indicates, at least for the Orthopedists in the study, that they were able to determine when they were potentially inaccurate.

As noted, attending staff were not used for this study. Presently the Emergency Department is covered with Orthopedic House Officers and an Attending Orthopedist as backup. Again, the intent was to utilize resources as closely to the current clinical situation as possible.

Compensation as well as legal responsibility for consultations performed at a distant site also have not been reported in the literature. It is expected these issues will be examined in the future as this technology is further harnessed for applications such as the one examined in this limited pilot study. Clearly, further investigation in this subject is warranted, however, sufficient data has been collected to support a larger study entailing a greater number of variables.

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